A FIVE STAGE IMPROVEMENT PROCESS
FOR SOLID WASTE COLLECTION SYSTEMS

A FIVE-STAGE IMPROVEMENT PROCESS
FOR SOLID WASTE COLLECTION SYSTEMS

This publication (SW-131) was written
for the Federal solid waste management programs
by KENNETH A. SHUSTER

U.S. ENVIRONMENTAL PROTECTION AGENCY
1974

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 - Price $1

An environmental protection publication (SW-131) in the solid waste management series

FOREWORD

A five-stage improvement process for solid waste collection systems, developed by the Office of Solid Waste Management Programs (OSWMP) of the U.S. Environmental Protection Agency, has been used extensively to evaluate residential solid waste collection systems and make cost-saving changes. Development of the process started with many time-and-motion studies and evaluations of residential collection systems throughout the United States. The process was formulated, refined, and successfully tested through OSWMP's program of technical assistance to cities.

This report summarizes the techniques of the five-stage improvement process. Some of the techniques are discussed in more detail in other reports: *User's Manual for COLMIS, A Collection Management Information System for Solid Waste Management*, *Heuristic Routing for Solid Waste Collection Vehicles*, and *Decision-Makers Guide in Solid Waste Management*.

The five-stage improvement process is applicable to both public and private residential solid waste collection. It is designed to provide a methodical procedure for evaluating, designing, and implementing improved collection systems. It also provides information and guidelines on the many possible alternatives in solid waste storage and collection. By applying the process, local governments and private haulers can achieve improved service and cost savings.

—ARSEN J. DARNAY
Deputy Assistant Administrator
for Solid Waste Management

CONTENTS

A FIVE-STAGE IMPROVEMENT PROCESS

for solid waste collection systems

This report briefly outlines a five-stage improvement process for solid waste collection systems, developed by the U.S. Environmental Protection Agency's Office of Solid Waste Management Programs (OSWMP). The process is the culmination of time-and-motion studies conducted on about 40 different systems (both public and private), analysis of OSWMP management information system data from about 35 communities (again, both public and private systems), and information derived from EPA solid waste demonstration and technical assistance projects.

The five-stage improvement process is a systematic way to evaluate existing solid waste collection systems and design new ones. It can help managers identify inefficient policies and causes of excessive costs, and develop more efficient systems to overcome these problems. It is designed to be easy to learn and apply, and cost effective.

The process has been used extensively and successfully in OSWMP technical assistance projects, with some dramatic results. For example:

- River Rouge, Michigan, cut its residential collection cost by 58 percent through improved routing and collection methods
- Portland, Maine, increased service and frequency while still saving $30,000 per year
- Akron, Ohio, designed a new system that saved an estimated $2.2 million per year, or $30 per residence per year
- Huntington Woods, Michigan, increased the efficiency of its system and reduced costs by 65 percent in 3 years

Complete descriptions of these and other local systems, indicating how the five-stage improvement process was applied, are given in the chapter "The Process in Action."

why improve solid waste collection?

Solid waste collection and disposal systems in our society are in transition, for only recently has significant interest been turned toward the problem of solid waste. Here are some of the factors that have brought about this new interest: The visibility of solid waste management has increased as the amount of solid waste generated has increased and local municipalities have faced crises of high collection costs, strained budgets, dirty inner cities, labor problems and strikes, and the even more difficult problem of finding new disposal sites. These problems have prompted U.S. mayors and city councilmen in a recent survey to vote solid waste management as the major national problem in cities today. (It was not considered the major problem on the West Coast, where solid waste collection has been better managed.)

Increasing concern for the environment has resulted in greater attention to the effects of poor solid waste management, particularly pollution of water and air and degradation of land. Growing awareness of the need to conserve energy and materials has made resource recovery from waste a vital issue.

The financial world has recently shown interest in solid waste management, as demonstrated by the recent emergence of agglomerates of private haulers with improved financial leverage and more sophisticated approaches.

Finally, as far as solid waste collection systems are concerned, interest has been stimulated by OSWMP studies that have shown that substantial savings and improvements are possible. This new attention means that cities and private haulers that do not work on improving their systems will be left behind with ineffective and costly collection systems. Indeed, the current trend is toward improvement in both the public and private sectors.

what are the objectives?

Solid waste collection is the process of picking up from many storage locations the discards or wastes of a community and hauling them to a processing or disposal site.

The collection system objectives should be:

Environmental protection: to protect the health and aesthetic conditions of the living environment by hauling the waste away in a sanitary fashion

Convenience: to provide a desired level of service (e.g., in terms of frequency and point of collection)

Continuity: to provide for stability of this vital service

Resource recovery: to reclaim and conserve natural resources

Safety: to store and collect the waste in as safe a manner as possible

Efficiency: to achieve all these objectives with the highest productivity and least cost

It is against these objectives, then, that effectiveness should be measured in evaluating the performance of collection systems.

Most solid waste collection systems concentrate on *picking up the waste on schedule and hauling it away,* which generally satisfies only the objectives of environmental improvement, convenience, and continuity of service. Resource recovery is a developing objective of solid waste collection, and will become more important as it becomes more feasible and more clearly profitable. Whereas the other objectives are definitely local in scope, resource recovery is also a national problem, in the sense that incentives and legislation on the national and State levels must be established to encourage it. With increased local pressures by ecology-minded citizens, however, local governments are contributing to this national objective.

As for the safety objective, it should be noted that solid waste collection is the most hazardous occupation in the United States, as measured by injuries and lost time per man-hour worked. New safety standards, better storage and waste-handling practices, and training programs for collection personnel are improving this situation.

One objective that is often overlooked is efficiency. Studies conducted by OSWMP provide clear evidence that a large portion of the nation's solid waste collection systems are inefficiently run and that the low productivity of these systems results in unnecessarily high costs for collection service. This is true of both public and private collection systems.

This report is concerned with ways to attain efficiency—to increase productivity and decrease costs—in those aspects of a collection system which may be modified at the local level.

what factors affect productivity?

By definition, increased productivity means more services (i.e., separate pickup points) collected per hour, and more tons collected per hour. Many people think that the only way to increase productivity is for the laborers to work harder, and that low productivity is the laborers' fault. In general, however, this is not so. Higher productivity can be achieved through improved storage and collection methods such as better routing, more efficient storage devices (e.g., plastic sacks instead of 55-gallon drums), collecting one side instead of two sides of a street at a time, reduction in crew size, and using mechanized systems (bulk bins). These improvements make the task easier for the collectors. If productivity remains low, the management may be at fault. It is management's responsibility to design systems, to set fair and equitable tasks, and to be informed about what is going on in the system and on the routes.

There are many reasons why managers, in both public and private systems, have failed to pursue the objective of higher productivity and lower costs. Some of the major reasons are: (1) preoccupation with the daily management concerns associated with picking up the waste on the scheduled collection day, such as how many laborers are present each day and how many trucks are operable, handling requests, and billing; (2) the degree of management effort required to evaluate, design, and implement change and to overcome the natural resistance to change—it is easier to maintain the status quo when, after all, the waste *is* being picked up on time; (3) lack of systematic management techniques to guide decision-making; (4) reliance on overstaffing to ensure an adequate labor force to collect the waste on time without analyzing efficiency and need; (5) inability to acquire new or efficient equipment due to budgetary or financial constraints; this results in operational inefficiencies, lost time, and higher maintenance and repair costs, and therefore higher costs in the long run.

The five-stage improvement process has been designed with these constraints in mind. It is very simple, yet it enables a more sophisticated approach to management.

what are the five stages?

The five stages of the process are: (1) review existing policies and methodologies and the alternatives to these, including institutional structure and objectives of the delivery system, (2) macro-routing: determine the optimum assignment of the daily collection routes to existing or proposed processing and disposal facilities, (3) perform route balancing and districting to determine a fair day's work, to evaluate crew performances and costs for different policies and methods, and to divide the collection areas into equal workloads for each crew, (4) micro-routing: determine the path or route the collection vehicle is to follow as it collects waste from each service in a specified area, (5) implement changes.

These stages are generally performed in the order listed (Figure 1), with the exception that some of the policies and methodologies of stage one should be determined or revised after the route evaluations of stage three have been performed. Implementation, of course, must be considered in each stage.

OSWMP has developed several tools that are readily usable by local sanitation systems in the improvement process. The tools and the particular stages at which they may be applied are: the Collection Management Information System, which is described in the Appendix (stages 1-5); macro-routing computer model (stage 2); mathematical model for route balancing (stage 3); and a heuristic procedure for micro-routing (stage 4).

Each of these tools is briefly discussed in this report as it relates to the five-stage improvement process. Reports discussing specific tools in greater detail are available from EPA on request (see p. 38).

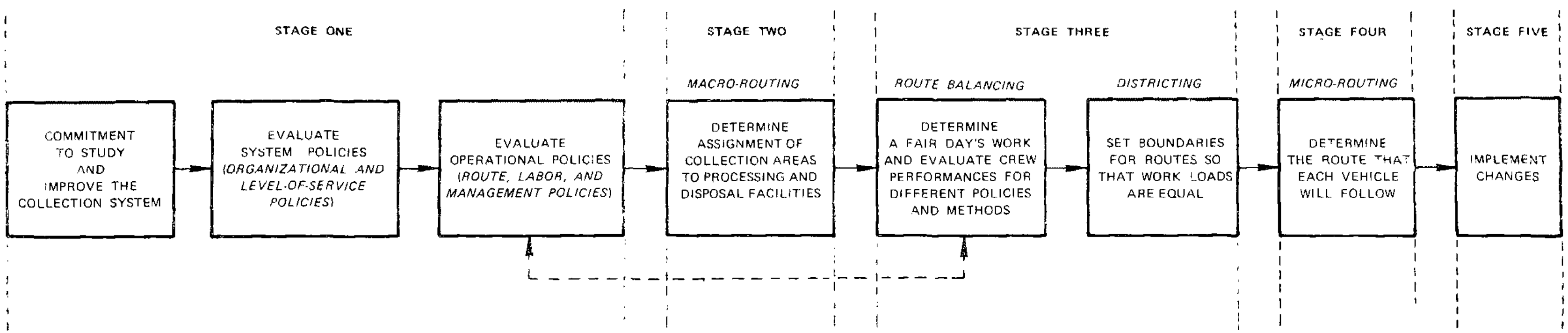


Figure 1. This flow chart summarizes the five-stage improvement process for solid waste collection systems.

STAGE 1.

review existing policies and methods and their alternatives

The first stage in the five-stage improvement process is to review the existing policies and methods and their alternatives. Collection system policies may be conveniently divided into system policies and operational policies, according to the management level at which decisions are made.

system policies

System policies are generally decided by top city management (mayor, manager, or council), or directly by the citizens, or by a private hauler. They include policies relating to general organization and to level of service.

Organizational policies determine who is responsible for delivering, regulating, financing, and controlling the desired service. They include institutional arrangements (public, private, or combinations; open competition, franchising, contracting, or utility concept; competition or monopoly; regulation and controls; profit or nonprofit), financing methods (user charges, based on point of collection, number of containers, size of containers, frequency of service, etc., versus special tax or general revenues; the budget process; bonds; leasing), billing system and policies, subsidization of particular groups (residential versus commercial; suburb versus inner city versus outer city), and legal issues (solid waste ordinance, contracts, licenses and fees, ownership of waste, other regulatory and enforcement issues).

Level-of-service policies determine the amount of service to be delivered: who will receive service (residential, commercial, apartments), citizen option versus mandatory service, point of collection, frequency of collection, type of storage devices (paper or plastic sacks, cans, bulk bins, etc.), limitation on amount of waste or number of containers that will be collected, mechanical collection, collection of yard wastes and bulk items (furniture, white goods), separate collection of garbage, or of newspapers for recycling, inner city cleanup programs, service for the elderly and handicapped, and point of collection for corner-lot residences.

operational policies

Once system policies have been determined, then the appropriate decisions can be made regarding operational policies, which include route, labor, and management policies. The operational policies are generally made at the operating level (e.g., by the department of public works or the private contractor), although the labor policies are frequently determined in conjunction with labor unions and civil service commissions.

Route policies would cover: crew size, type and size of equipment; whether drivers will collect; "limousine" service (truck chauffeurs crew to and from home, lunch, etc.); shuttle system (instead of accompanying truck and driver to disposal site, crew continues to collect on other routes); reservoir system (central area is picked up by all crews as they finish their routes; no crew can go home until central area is collected); whether collection vehicles must be full before they can go to the disposal site; whether times and sites for lunch and breaks are fixed; scheduling (hours of operation, days of operation, commercial and other discrete accounts, seasonal variations); vehicle routings and districts; whether one side or both sides of the street are collected in one pass; whether vehicles are allowed to back down short street segments or to make U-turns; how to route steep hills; what to do about enclosures or other obstacles (fences, porches, garages, steps); dealing with excessive haul time (larger vehicles, greater compaction, or transfer stations may be indicated); and making seasonal variations in routes based on differing waste amounts.

Labor policies are concerned with the wage structure; the career ladder and seniority system; training programs; measures to prevent accidents and protect health; problems of absenteeism; and incentive systems (monetary bonus, or task completion system—workers can go home when assigned task is done).

Management policies include the organizational structure of management, management information systems, cost-accounting systems, the system for handling requests and complaints, supervisory communications system (radio contacts, supervisory vehicles and staffing), and the public relations program.

are present policies being followed?

Examples abound of instances where official and stated policies and methods differ from what happens in actual practice. Frequently, key management personnel, who should know what is happening, do not. For example, one community stated it had twice-a-week collection, yet investigation showed that most residences were serviced three times a week and others four or five times a week. This was because the crews were on an incentive system whereby they could go home when their routes were completed for the day, but the crews believed that management would be upset if they completed their assigned routes in less than 4 to 5 hours (which they could easily do), so they would continue to collect until a "reasonable" amount of time passed. This practice enabled great flexibility in the daily schedule, including very long breaks. The management of this system had never determined a fair day's work and did not realize what was happening.

Another community had an ordinance which prohibited the use of plastic sacks and 55-gallon drums. Yet, a survey revealed that 50 percent of the storage containers were plastic sacks and 6 percent were drums. Management knew there was extensive use of plastic sacks (which they were willing to overlook) but did not realize there were any drums being used. Management in this same community reported that their method was to collect one side of the street at a time; yet, in actual practice, two sides were collected at the same time.

Two communities reported a 7- to 8-hour workday with a reasonable amount of overtime as the fair day's task, yet a study showed the crews taking 2½- to 4-hour breaks throughout the day to collect this overtime.

One community reported a 1½-hour round-trip haul time because of traffic and queues at the incinerator and even complained to the incinerator operator about the queues, yet observation showed that the haul time was actually 45 minutes to an hour, with the rest spent congregating after emptying at the incinerator.

Another community reported that drivers were required to collect wastes and did so, yet observation showed that even at heavy stops they did not get out of the cab.

Several communities and private haulers reported that scavenging by the collectors was prohibited, yet observers found that much crew time was spent in careful scavenging operations, including the use of a salvage barrel in the hopper of one rear loader, which had to be removed each time the compactor was used.

One community with backyard collection said the collectors were not permitted to go within garages, fences, or other enclosures, but many were observed doing this.

One community reported they had three-man crews, when all crews were frequently observed to have four men.

Two communities did not realize their collectors were picking up from substantial numbers of noncity customers (nonsubscribers and commercial accounts).

One community contracted a private hauler at a fixed collection contract price plus a disposal charge based on tonnage. Their citizens seemed to be generating more waste than all the neighboring communities, but investigation showed that the hauler was actually charging the contracted community for disposing of other communities' wastes. (The contractor was promptly fired.)

Many communities do not have a cost-accounting system and do not know how much collection actually costs them.

As these instances indicate, many solid waste managers have not kept themselves informed about how their collection systems are actually operating, yet such awareness is the necessary base for proper management.

CHECKLIST OF POLICIES AND PRACTICES

- I. System Policies
  - A. Organizational Policies
    1. Institutional arrangements
    2. Financing methods
    3. Billing system
    4. Subsidization of particular groups
    5. Legal issues
  - B. Level-of-Service Policies
    1. Who receives service
    2. Citizen option versus mandatory service
    3. Point of collection
    4. Frequency of collection
    5. Type of storage devices
    6. Limit on amount of waste or number of containers
    7. Mechanized collection
    8. Yard wastes
    9. Bulk items
    10. Separate collection of garbage or recyclable materials
    11. Inner city cleanup programs
    12. Service for elderly and handicapped
    13. Corner-lot residences
- II. Operational Policies
  - A. Route Policies
    1. Crew size
    2. Type and size of equipment
    3. Whether drivers collect
    4. "Limousine" service
    5. Shuttle system
    6. Reservoir system
    7. Whether collection vehicle must be full before going to disposal site
    8. Times and sites for lunch and breaks
    9. Scheduling
    10. Vehicle routings and districts
    11. One-side or both-sides-of-street collection
    12. Whether vehicles can back down short street segments or make U-turns
    13. Routing on steep hills
    14. Dealing with enclosures and other obstacles
    15. Dealing with excessive haul times
    16. Seasonal variation of routes
  - B. Labor Policies
    1. Wage structure
    2. Career ladder, seniority
    3. Training
    4. Safety measures and preventive health care
    5. Insurance and pension plans
    6. Holidays, vacations, sick leave
    7. Absenteeism
    8. Incentive system
  - C. Management Policies
    1. Organizational structure
    2. Management information system
    3. Cost-accounting system
    4. Handling requests and complaints
    5. Supervisory communications system
    6. Public relations program

STAGE 2.

macro-routing: determine the optimum assignment of daily collection routes to discharge points

The second stage, macro-routing, is concerned with assigning each collection route to a particular disposal site or processing facility so that the total pattern of assignments will result in optimal use of facilities and will minimize total costs.

In a simple case, where there are only one or two facilities, or where all the facilities are landfills, the solution is readily apparent. If all discharge points are sanitary landfills, the optimum solution would be to minimize the round-trip haul time for each route, taking into account queue times at each site. This generally means hauling to the closest landfill.

However, a complex system may involve many different facilities, such as shredders, balers, incinerators, energy or materials recovery facilities, transfer stations, compost plants, and landfills. In such a case, a computer program may be required to optimize use and siting of facilities. OSWMP has developed a model program which is currently being tested and refined, and will be available in 1975.

For the complex case, the following factors must be considered in relation to each other in optimizing the system:

Fixed and operating costs of each facility. Since certain facilities, such as incinerators, have a very high initial cost and a relatively low day-to-day cost (even when operated for more than one shift per day), the cost of increasing the facility throughput (tons per day) is relatively low. The fixed charge (high initial investment) for such facilities complicates the optimization analysis.

Short- and long-range capacities of each facility. The capacity and volume-reduction capability of a facility may affect the operation of other facilities. For example, an incinerator or shredder may have a maximum daily capacity of 200 tons; if it is not operating at capacity, it may be desirable to increase the throughput in order to extend the life of the landfills in the system.

Cost of round-trip haul for each route, accounting for queues at each facility. This is the total off-route transport and discharge cost incurred each time the crew goes to a disposal facility.

Effect of facility on collection equipment. Many disposal sites have poor access roads and discharge areas, which result in flat tires and stuck vehicles (causing wear on transmissions and differential gears as well as lost time); most processing facilities, on the other hand, have concrete platforms to discharge from.

Once macro-routing is done, the round-trip haul times for specific collection areas can be estimated, and this information is needed for the next stage, route balancing and districting.

STAGE 3.

route balancing and districting: determine a fair day's work and divide the collection areas into equal workloads

Route balancing is the process of determining the optimum number of services that constitutes a fair day's work and dividing the collection task among the crews so that they have equal workloads. Route balancing can be used to (1) estimate the number of trucks and men required to collect waste in a new or revised solid waste system, (2) develop or evaluate a bid price for a collection contract, (3) evaluate crew performances, as a whole or individually, (4) determine a fair day's work or a work standard necessary for task and wage incentive (bonus) systems, (5) balance or equalize the workloads among collection crews, or (6) determine the optimum size for new trucks or optimize the use of existing trucks. Thus, route balancing is necessary if a new collection system is being instituted, if a major change in the present system (e.g., backyard to curbside collection) is going to take place, if the system is to be evaluated, or if a collection contract is up for bid.

Route balancing is accomplished by analyzing each component of time in the collection day, or how each crew spends its time (Figure 2). Adding these component times results in an equation for the total time in the workday (Y):

$$Y = a + b + n\,(c_1 + c_2 + d) - c_2 + e + f + g \quad (1)$$

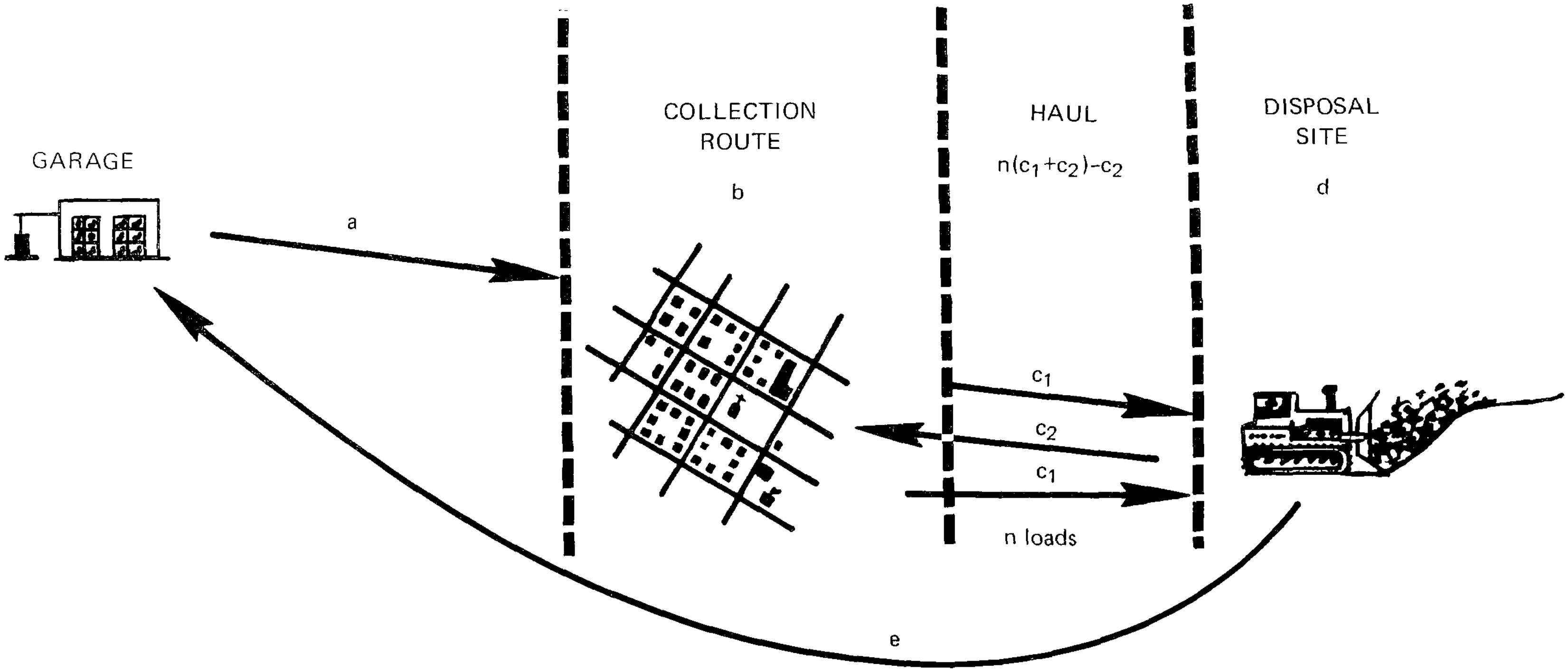
where a = time from garage to route
b = total collection time on route
n = number of loads
c_1 = time from route to disposal site
c_2 = time from disposal site to route
d = time at disposal site
e = time from disposal site to garage
f = time for official breaks
g = slack time: lost time due to breakdowns and other delays, incentive time, lunch time

This equation is the basis for determining a fair day's work and for route balancing.

The data required for this analysis are (1) time and distance data related to the components of the collection day, (2) the number and type of services and where they are located, (3) the average amount of waste generated per service, including seasonal variations, (4) basic equipment and labor cost data.

One method for gathering this data involves using the Collection Management Information System (COLMIS), described in the Appendix. Values for each time variable are readily obtainable for any existing system from the COLMIS reports, or similar records. Each of these time elements may be compared for each route to ascertain their reasonableness.

In designing a new collection system, it is necessary to apply equation (1) to determine the appropriate number of services per crew per day, which tells how many trucks and men are required. Reasonable values for variables a, c_1, c_2, d, e, and f are readily obtainable. For example a, the time from garage to route, is easily derived by considering the distance and route covered and the reasonable driving time to traverse it. Likewise, the number of formal breaks to be taken is a policy decision and is typically two 15-minute breaks (in a task incentive system, crews frequently skip the breaks).



+f = TIME FOR FORMAL BREAKS

+g = SLACK TIME: ALLOWANCE FOR LOST TIME DUE TO BREAKDOWNS AND OTHER DELAYS, INCENTIVE TIME, LUNCH TIME

Figure 2. This schematic drawing of the components of a collection day depicts the elements of equation (1). It shows how the crew spends its day.

Variable n (number of loads per day) is based on the number of services per load (N):

$$N = \frac{x_1 x_2}{x_3} \qquad (2)$$

where x_1 = vehicle capacity (cu yd/load)
x_2 = vehicle density capability (lb/cu yd)
x_3 = lb/service/collection
N = number of services per load

Variable n is then determined by dividing the number of services that can be collected in the workday (calculated by the procedure which follows) by N and rounding up to the next whole number.

Variable b (total collection time on route) is a function of the number of services that can be collected per hour, or the on-route minutes per service. These values may be obtained in four ways: (1) using COLMIS or data from a similar system; (2) conducting time-and-motion studies on the existing system or a similar one; (3) using regression equations developed from data on similar systems; (4) implementing experimental routes and trying different crews. Obviously, the values for n and b, and the time per service, vary seasonally as the amount of waste per service varies. It is recommended, therefore, that values for n, b, and the time per service be calculated for the peak, normal, and low waste generation periods (Figure 3).

The steps necessary to determine the number of services per crew per day (a fair day's work), the number of men and trucks required, and the system cost are described in the following procedure. These steps are based on equations (1) and (2), and determine values for b (collection time), n (number of loads), and the number of services per crew per day. The time required for on-route collection and transport for each load is compared with the time that is left in the workday until the total time in the collection day is accounted for.

1. Select the level of service, truck type and size, and crew size.

2. Determine N (number of services per load) from equation (2) using normal waste generation rate.

3. Starting with Y, the total hours in the workday (e.g., 8 hours) from equation (1), subtract variables a, e, and f, and add c_2. Then subtract the round-trip haul time per load ($c_1 + c_2 + d$) and the collection time per load (services per load (N) times the minutes per service). Continue to subtract transport and collection times, load by load, until all the time in the workday is used up.

4. Multiply the resultant number of loads (including partial loads if any) by the services per load (N) to get the total number of services per day for each crew.

5. The number of trucks required is determined as follows (rounding the result to the next highest whole number):

$$\text{Trucks required} = \frac{\begin{pmatrix}\text{Total No.}\\ \text{services}\end{pmatrix}\begin{pmatrix}\text{Collection frequency}\\ \text{per week}\end{pmatrix}}{\begin{pmatrix}\text{Services per}\\ \text{truck per day}\end{pmatrix}\begin{pmatrix}\text{No. workdays}\\ \text{per week}\end{pmatrix}}$$

6. Calculate the annual cost of a crew and truck by adding vehicle costs and labor costs:

Vehicle cost = depreciation + maintenance + consumables + overhead + license fees and insurance

Labor cost = salary of driver + salary of collector(s) + fringe benefits + indirect labor + supplies (e.g., gloves) + administrative overhead

7. Evaluate the effects of peak and low generation periods on overtime and incentive time respectively by repeating steps 2 through 5 using peak and low generation rates.

8. Multiply the cost per crew (from step 6) by the number of crews needed (from step 5), and add overhead expenses including overtime

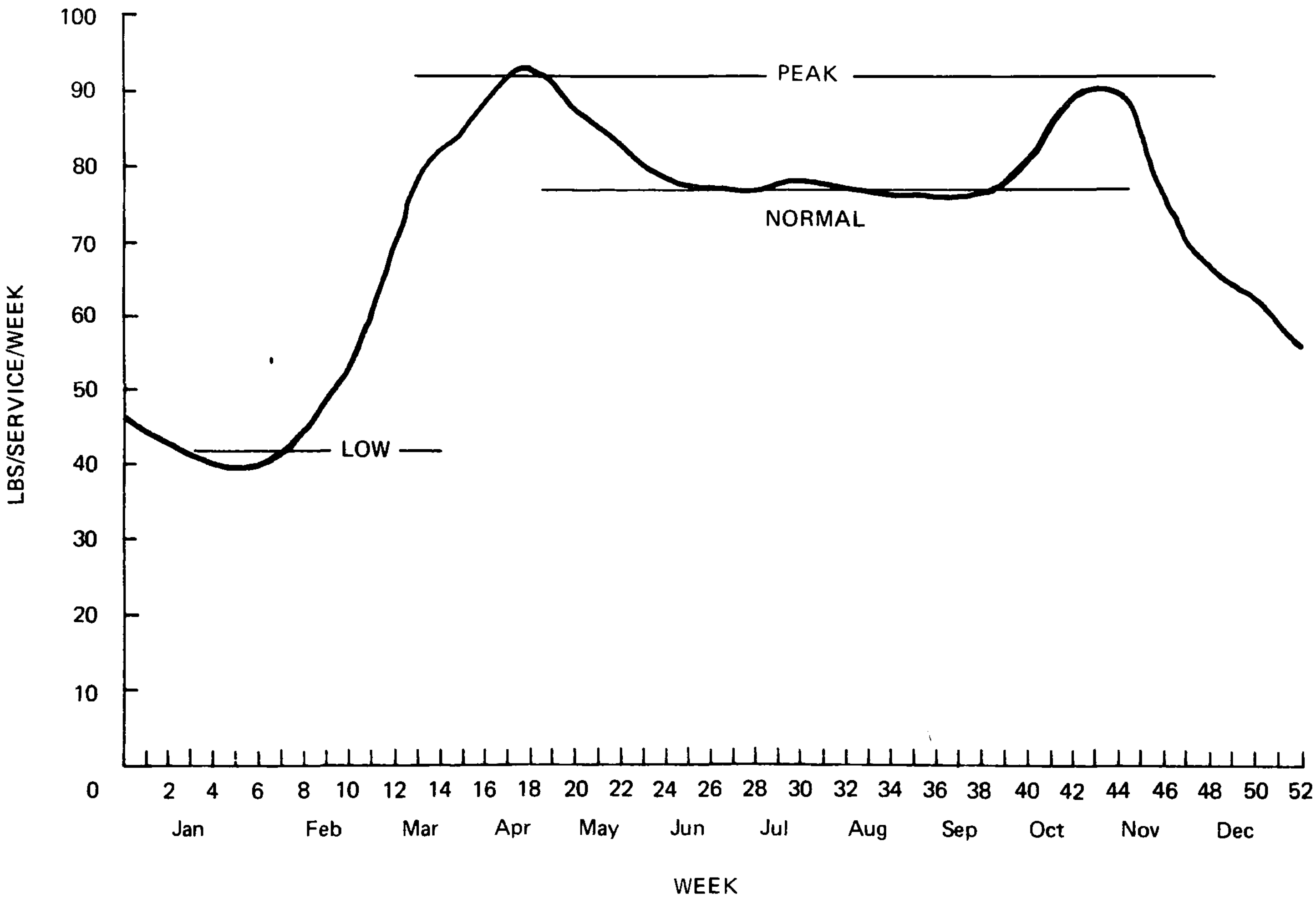


Figure 3. These seasonal variations in the amount of waste collected are typical for Northern cities. Such variations should be taken into account in computing the daily workload.

cost (from step 7) to obtain the total system cost. Divide the total cost by the total number of services to obtain the annual cost per customer.

9. Repeat steps 1 through 8 for any other level of service, equipment, crew size, or other system alternatives being considered. Comparison of crew productivities, system slack, and total cost (and cost per customer) for each system alternative helps give a clear picture of which alternative is most acceptable.

The slack time, variable g, is built into this procedure by rounding to whole numbers and by using conservative estimates. For example, if the average number of loads is 2.3 (step 3), the number of trips is three, giving a slack capacity of 70 percent for the last load for all trucks. Slack also results from rounding the number of trucks required up to the next whole number. For example, if the number of trucks required is 7.2 (step 5) then the actual number of trucks required is 8. If the number of services per truck per day is computed to be 650, based on 7.2 trucks (step 4), then the *actual* number of services per day for each of the 8 trucks is 585. This also means more slack in the number of loads. In this case, the actual length of the workday should be recalculated using 8 trucks and 585 services per truck.

Once the equitable number of services per crew (step 4) has been determined for each area, districting and micro-routing can be performed to develop the individual routes. *Districting* is the process of dividing the collection area into equal workload sections according to the day of the week, and then dividing each daily section into specific routes for each truck, based on the equitable number of services per crew determined by the route balancing procedure. Total collection and haul time should be reasonably constant for each route. Developing the daily routes may be done in conjunction with micro-routing or before. When they are done together, a starting point is selected and a path or route is developed (continuous and concentrated in an area) until enough services to make a route is reached. This process is continued until the whole collection area is routed.

In districting and micro-routing, natural boundaries should be utilized where possible for route boundaries. These include rivers, lakes, streams, mountains, valleys, railroads, highways, major roads, parks, cemeteries, hospitals, and other areas without services.

STAGE 4.

micro-routing: determine the path each collection vehicle will follow

The objective of micro-routing is to minimize the noncollection distance (repeat distance and streets with no services) and delay times (such as U-turns, heavily trafficked streets, and left turns) for each collection vehicle.

The typical collection route has evolved over the years, with new collection areas assigned to the crew with the lightest workload, resulting in fragmented and overlapping routes. Typically, the vehicle path is selected by the driver with no direction from management. In one such case, OSWMP designed a compact route that contrasts significantly with the existing driver-designed route (Figure 4).

the heuristic approach to micro-routing

OSWMP has developed a simple, noncomputerized "heuristic" or common sense approach to micro-routing based on the following rules of thumb:

1. Routes should not be fragmented or overlapping. Each route should be compact, consisting of street segments clustered in the same geographical area.
2. The collection route should be started as close to the garage or motor pool as possible.
3. Heavily traveled streets should not be collected during rush hours.
4. Services on dead-end streets can be considered as services on the street segment that they intersect, since they can be collected only by passing down that street segment. To keep left turns at a minimum, however, the dead-end streets should be collected when they are to the right of the truck. They must be collected by walking down, backing down, or making a U-turn.
5. When practical, steep hills should be collected on both sides of the street while the vehicle is moving downhill, for safety, ease, speed of collection, reduced wear on vehicle, and conservation of gas and oil.
6. Higher elevations should be at the start of the route.
7. For collection from one side of the street at a time, it is generally best to route with many clockwise turns around blocks.
8. For collection from both sides of the street at the same time, it is generally best to route with long straight paths across the grid before looping clockwise.

Heuristic rules 7 and 8 emphasize the development of a series of clockwise loops in order to minimize left turns, which generally are more difficult and time-consuming than right turns. Also, right turns are safer, especially for right-hand-drive vehicles.

9. For certain block configurations within the route, specific routing patterns should be applied.

routing patterns

As the router gains experience, he will recognize routings that are efficient for certain block patterns (Figures 5-8). Additional patterns may be developed and applied for specific situations.

data required

All the information required for routing can be recorded on community maps. First, indicate on the map(s) the number and type (residential, apartment, commercial, etc.) of services on each side of each street segment. Next, identify all one-way, dead-end, and heavily traveled streets. Indicate which corner-lot

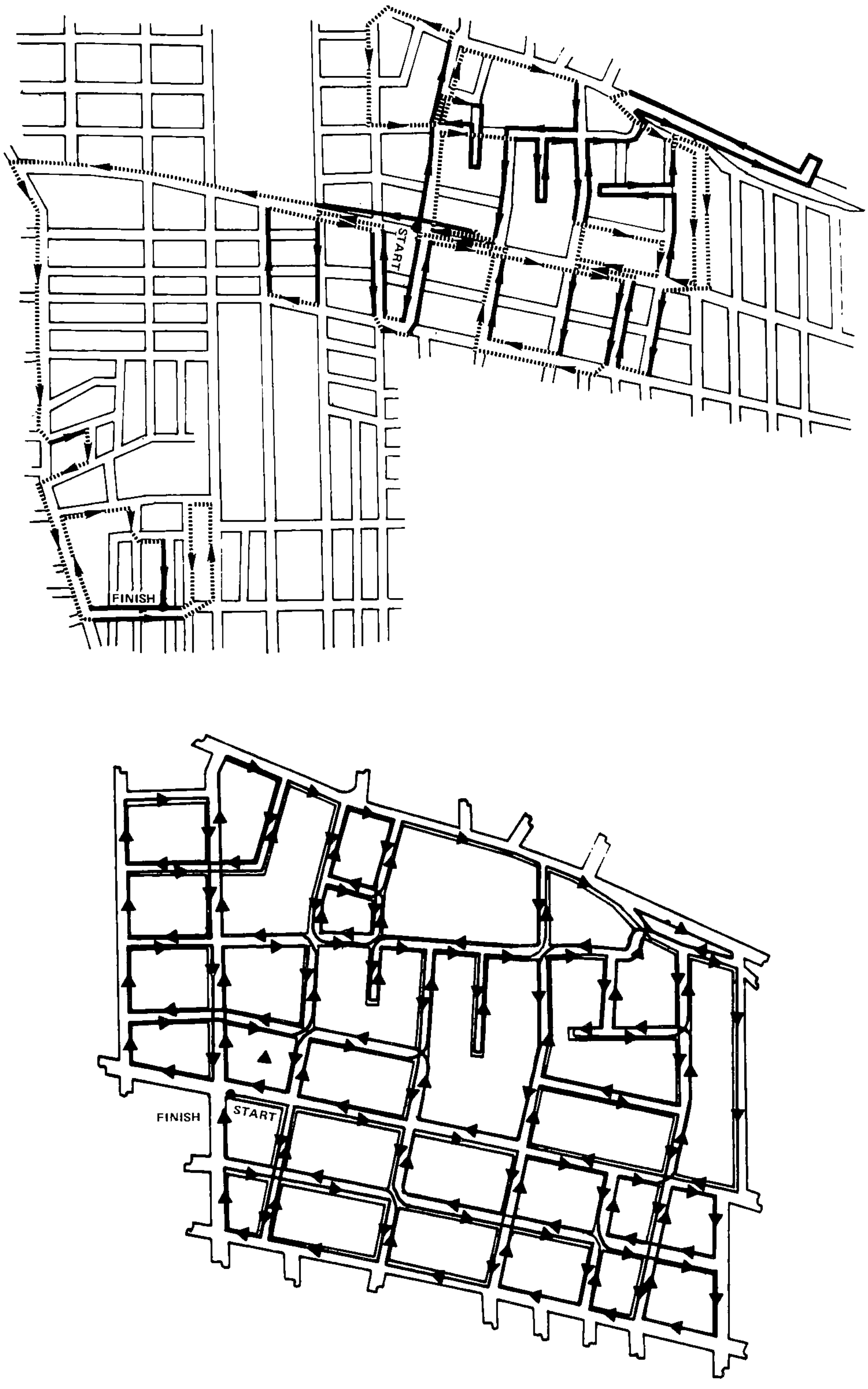
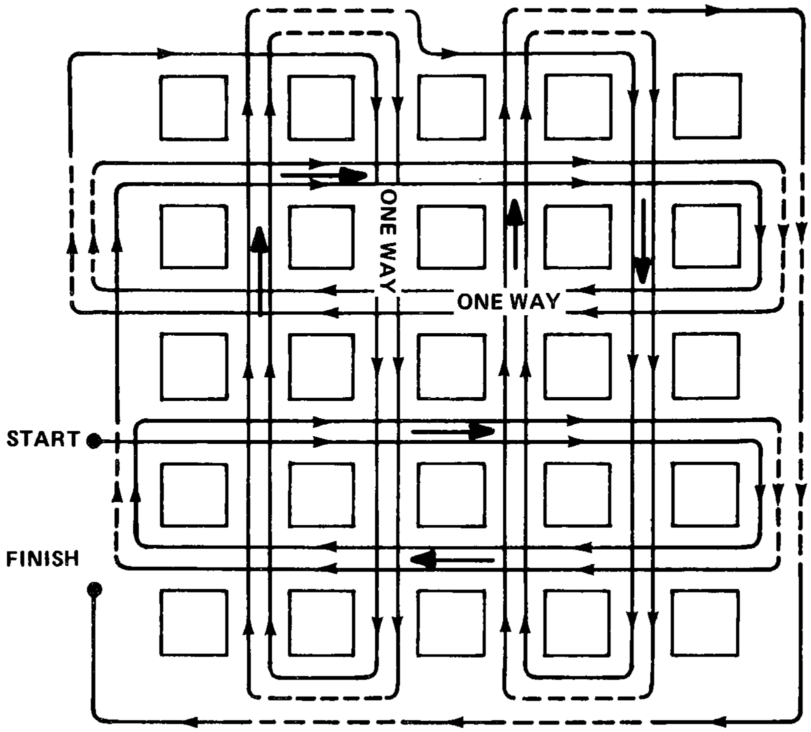
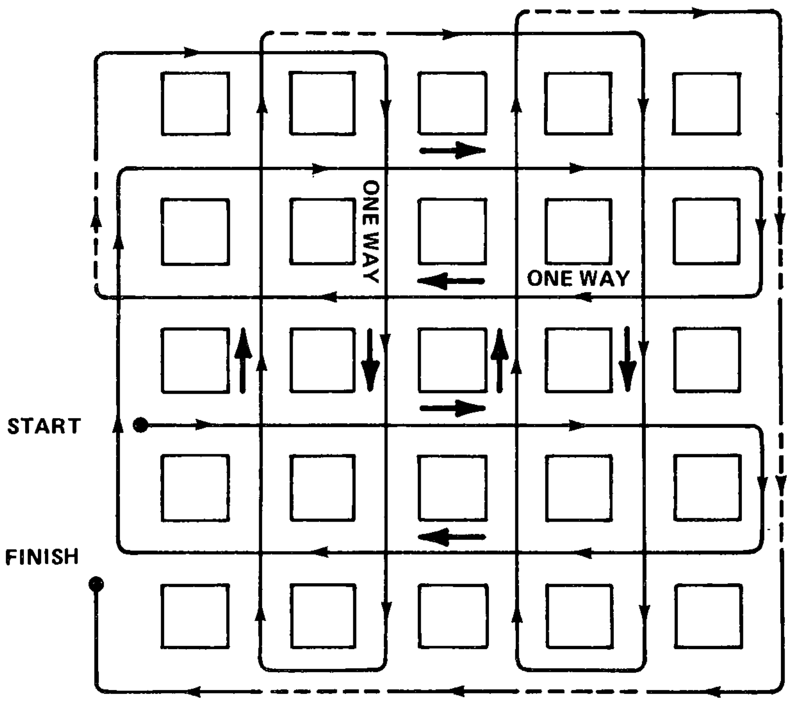


Figure 4. The typical collection route (top), selected by the driver, is fragmented. Its nonproductive segments are shown in dashes. The new collection route (bottom), designed using the OSWMP heuristic routing procedures, is compact and has no nonproductive distances.



ONE SIDE OF THE STREET COLLECTION



BOTH SIDES OF THE STREET COLLECTION

DIRECTION OF ONE-WAY STREETS

Figure 5. Specific routing patterns for multiple one-way streets. Note the clockwise movement.

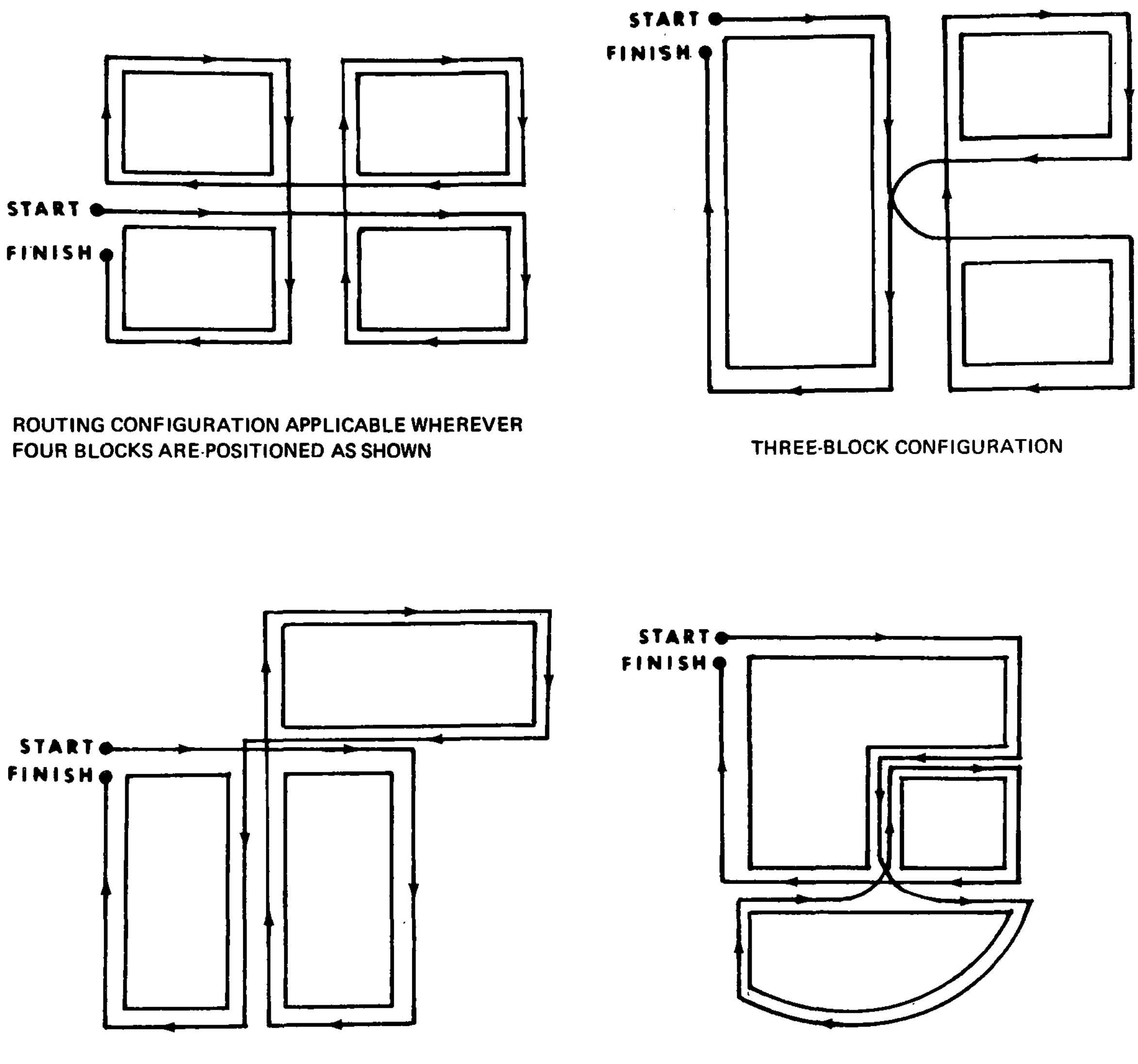
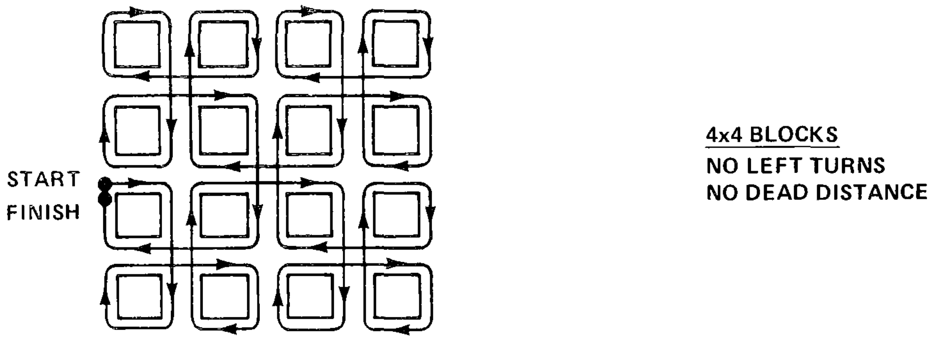
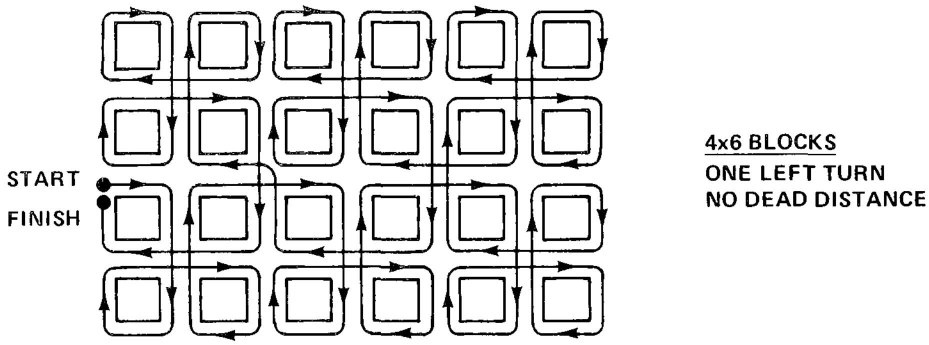


Figure 6. Some specific routing patterns for three- and four-block configurations. In all configurations, blocks may vary in size and shape.





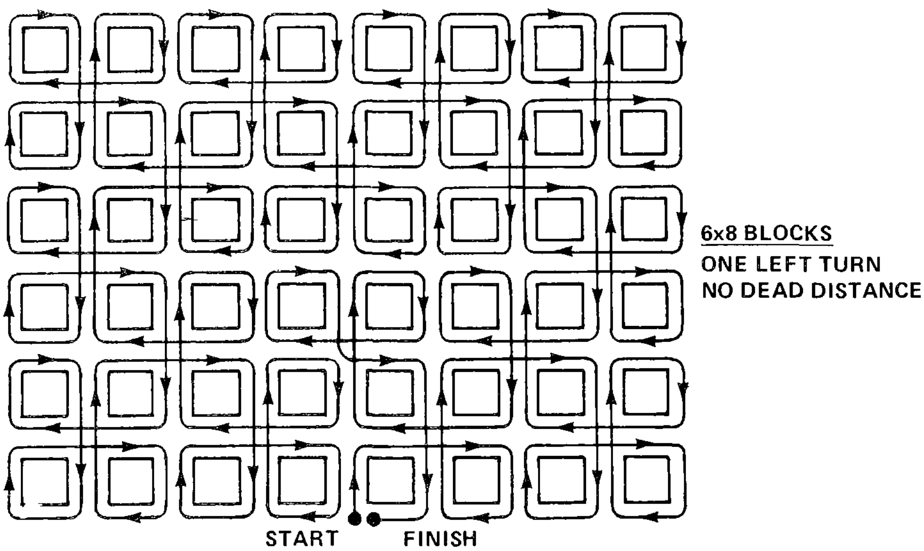
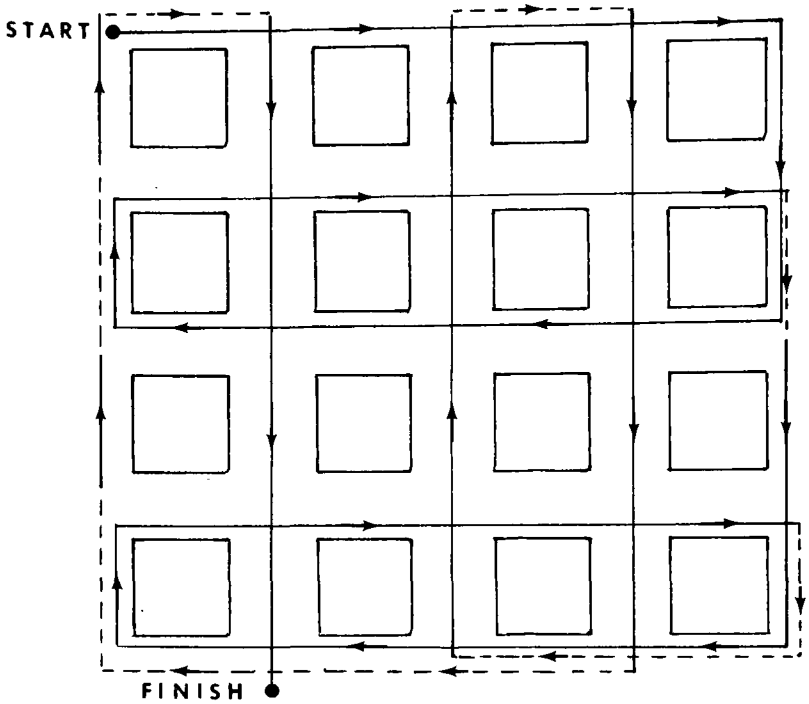
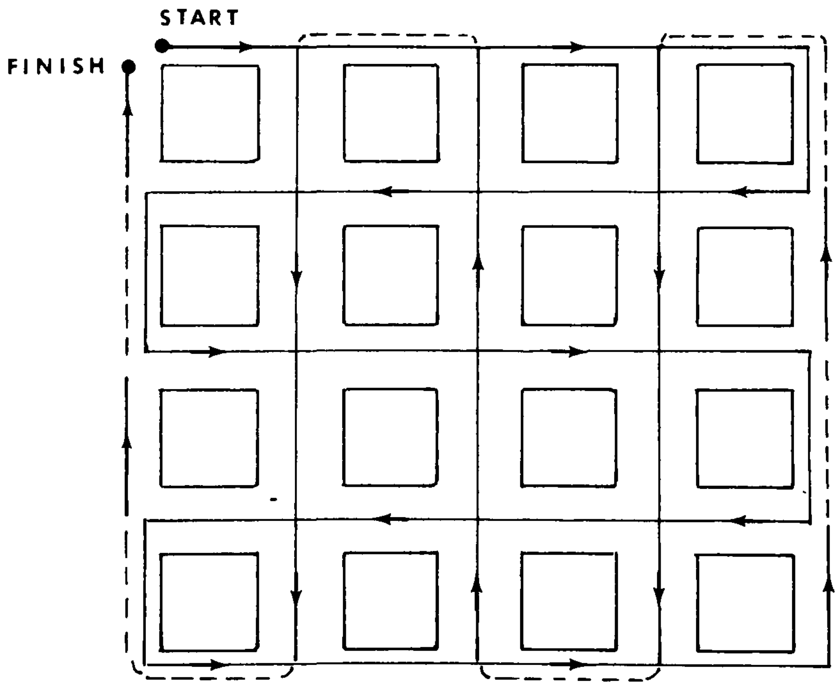


Figure 7. Combinations of the four-block pattern, with one-side-of-the-street collection. For this pattern to be applicable, at least one side of the grid must have an even number of blocks. Each of these routes uses the same routing pattern, with progression in a counter-clockwise direction. For the larger grids, once the outsideis routed, the inside is routed in a clockwise progression.



PATTERN A



PATTERN B

Figure 8. In specific routing patterns for both-sides-of-the-street collection, pattern A entails no left turns, and pattern B requires nine left turns. Dash lines represent "dead distance" or non-collection segments of the route.

residents (if any) should be asked to place their waste on a specific street segment. Finally, identify, for each street segment or service area, whether the crews are to collect one or both sides of the street on a pass.

grid simplification technique

In working out a routing problem, it is often helpful to simplify the grid. This is accomplished by combining blocks that have no services on the common street segments which face each other (Figure 9). The pattern and routing procedure can then be applied to this simplified grid.

applying the heuristic rules

The heuristic rules are guides which, used in conjunction with specific routing patterns, help in rapidly and systematically developing efficient routes.

Using the map marked with the required data and divided into specific route areas for each truck, identify block configurations where patterns may be applied. Design the route by connecting these patterns and other street segments into a continuous path, using the heuristic rules to minimize dead distance and delay times (Figure 10).

If the routing is done before the daily districts have been divided into specific route areas, use the same approach of identifying patterns and applying the heuristic rules to develop a continuous route, but keep a count of the number of services that have been included in the route. Terminate the route when the number of services is approximately that determined to be reasonable for a fair day's work.

Repeat the routing procedure, applying the heuristic rules and patterns, until the whole community is routed. When developing the route, keep in mind that natural barriers (highways, rivers, etc.) make good boundary lines.

In applying the heuristic rules and patterns, the router should look ahead and behind several street segments and ask these questions: Have any street segments with services been left behind that will require a long dead distance to return and pick up? Are there already some long dead distances that might be reduced through slight modifications? Are there any peculiar or unique characteristics of the area which should be considered? Are there any patterns that can be utilized in the routing?

Once the initial route layout has been determined, the route should be retraced and alternate routings or modifications attempted wherever long dead distances exist. Note, however, that to evaluate *all* possible routing alternatives is a formidable task that even computer program models do not attempt.

The heuristic approach to routing is explained further in the report *Heuristic Routing for Solid Waste Collection Vehicles.*[2]

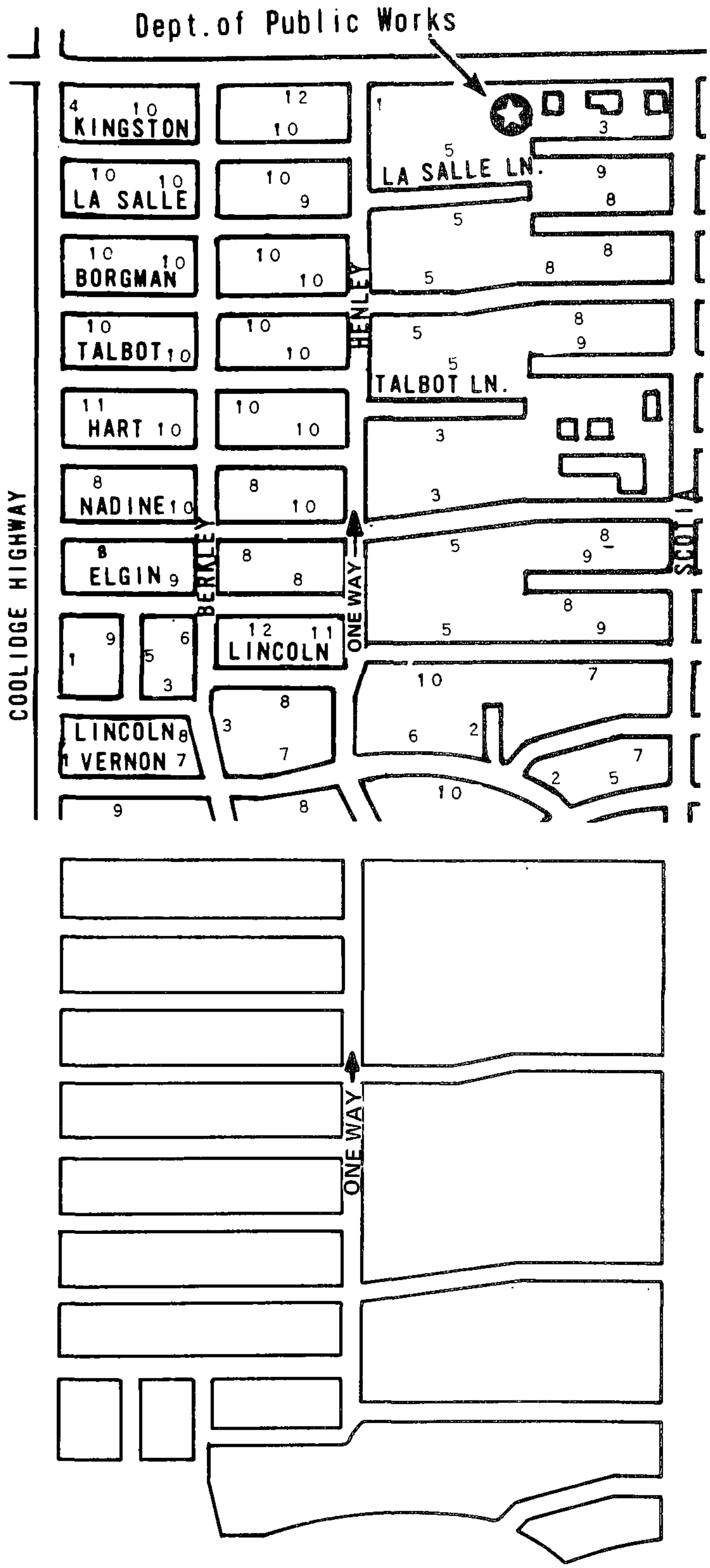


Figure 9. In the grid simplification technique, blocks with no services on common street segments are combined before routing.

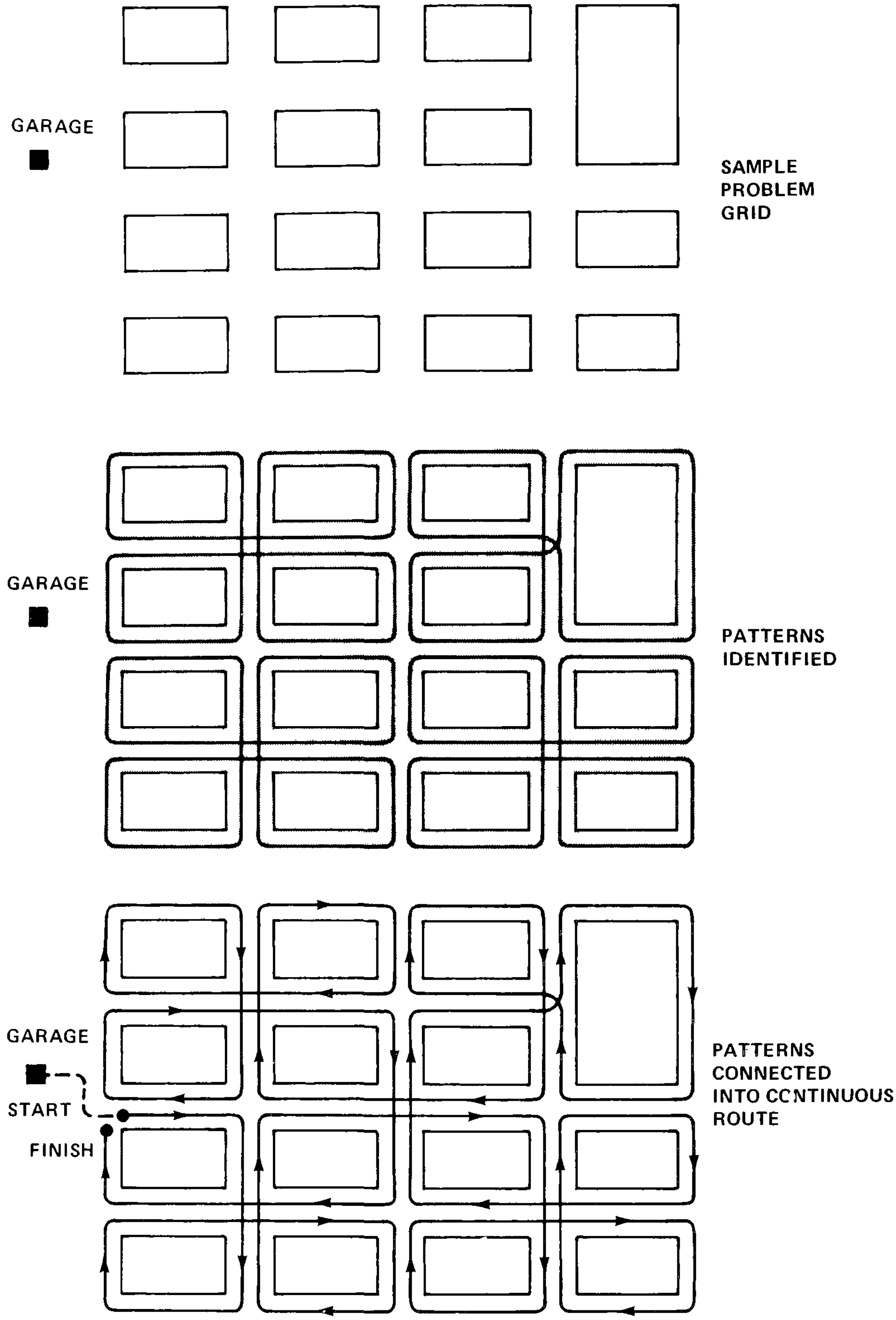


Figure 10. Example showing pattern method of routing. This solution has no dead distance and two left turns.

STAGE 5.

implementing changes

The foregoing analysis and tools are useless unless they provide solutions which can be implemented. People generally resist change, even if it is beneficial. A good implementation program must, therefore, be developed and tactfully applied to reduce this natural resistance.

Implementation must be considered throughout the improvement process, and appropriate authorities and groups fully informed in a timely fashion. The groups involved in the changes usually include citizens, the management team, collection crews, and city officials. Each group must be informed about what is expected of it in the new system, and each group should be included, where appropriate, in the development as well as the implementation phase of improving the solid waste collection system.

Citizens are directly affected by changes in the point of collection, the frequency of collection, the day and hour of collection, and the type of storage device. In designing a new system, it is usually a good idea to minimize the number of citizens who will have to change their day of collection. These citizens must be notified of their new collection day and the date the change will take place.

All citizens in the community—even those whose collection day will not change—should be informed that the solid waste collection service is being altered. Residents often become accustomed to collection at a specific time of day and may set their waste out accordingly, or they relate their own time of collection with that of their neighbors across the street or around the corner, which may have changed. Thus informing everyone should minimize missed collections.

The most extensive education effort will usually be directed toward the citizens, and several media are available. One of the best is a letter from the mayor or city manager explaining the reasons for the changes and how they may affect the citizens. Such a letter emphasizes the endorsement by the city management for the new system, and may include a telephone number to call for further information (Figure 11).

Another good way to notify the citizens is through flyers (Figure 12). The letter and flyers shown here are similar to those used in Kansas City, Missouri, during their effective implementation of a change in their system that took effect in March 1971. Note that the flyer is simple, yet it gives all pertinent information. The map helps residents conceptualize the collection area and acts as a check to assure that the flyer was delivered in the correct area. In Kansas City, the cards were color-coded by day of the week; this helped in answering phone inquiries from the citizens, since the area being discussed could be quickly identified.

Other methods that can effectively inform the public include television and radio announcements, and articles and notices printed in local newspapers. Even with an initial multifaceted information program, it requires time and patience to gain complete citizen understanding and cooperation. Extra office personnel and telephone lines to receive complaints and questions during the changeover may be desirable. Finally, using savings as they accrue from the new collection operations to postpone rate increases or decrease rates, upgrade the cleanliness and appearance of the trucks, replace unreliable trucks, provide uniforms for the collectors, or improve the disposal situation certainly helps sustain good public acceptance.

The group which is ultimately responsible for designing, implementing, and managing improved collection systems is the solid waste

Office of the Mayor

Julius C. Jones, Mayor

City of Anytown, USA
Heart of America

30th Floor, City Hall
Anytown, USA 64106

February 12, 1973

Councilmen at Large

Joseph Hall
1st District

James Smith
2nd District

William Glenn
3rd District

Thomas Rose
4th District

Mark Jones
5th District

Paul Hogan
6th District

District Councilmen

Robert Phillips
1st District

Charles Connolly
2nd District

Alan Michaels
3rd District

Peter Robbins
4th District

William White
5th District

James Myers
6th District

Dear Citizen:

On Monday, March 5, 1973, we will introduce a new City-wide refuse collection system designed to decrease the City refuse budget while still providing the same level of service to you, the citizens.

This savings is made possible through the thorough evaluation of our refuse collection system using the latest of management tools and implementing improved collection techniques.

The collection service will continue to be once-a-week curbside collection. We have, however, revised the City ordinance to permit the use of plastic sacks, which we encourage you to use. Enclosed is a brochure explaining the advantages to you and to the City through the use of plastic sacks, and some helpful hints on bag usage and refuse storage.

The only change affecting the citizens directly is a change for some in their day of collection. We have tried to minimize the number of citizens that must change their day of collection. This new collection system means, however, that in most instances the time of day that the collectors collect from each residence will change. The enclosed map shows the day of collection for each area. Please note when your new day of collection will be starting March 5.

Please help our sanitation men provide service to you during this change-over by having your waste put out by 7:00 a.m., the time they start to collect.

If you have any questions or suggestions, please call 684-4311.

Thank you for your cooperation in this effort.

Sincerely,

Julius C. Jones

Julius C. Jones
Mayor

Figure 11. Sample letter from a mayor to citizens notifying them of a change in the collection system.

Important Notice

Beginning March 5, 1973
Your New Refuse Collection Day will be

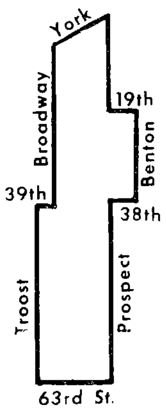
tuesday

There will be no collection on the following holidays:

May 28, 1973	*October 22, 1973*
September 3, 1973	*December 25, 1973*
October 8, 1973	*February 18, 1974*

If a holiday is observed on Monday or Tuesday, your collection day for that week will be WEDNESDAY.

For information call 254-7417



Public Works Department
Refuse Division
Anytown, U.S.A.

Important Notice

Beginning March 5, 1973
Your New Refuse Collection Day will be

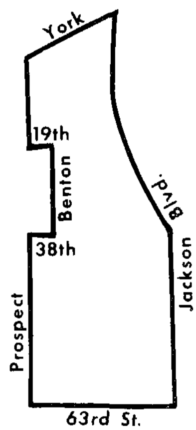
wednesday

There will be no collection on the following holidays:

May 28, 1973	*October 22, 1973*
July 4, 1973	*December 25, 1973*
September 3, 1973	*February 18, 1974*
October 8, 1973	

If a holiday is observed on Monday, Tuesday, or Wednesday, your collection day for that week will be THURSDAY.

For information call 254-7417



Public Works Department
Refuse Division
Anytown, U.S.A.

Figure 12. Flyers are an effective medium for informing citizens of changes in the collection system.

management team, from the system manager down to the route foreman. Their participation in the new system design, particularly route design, serves several purposes. First, members of the solid waste management team are generally the people who, besides the collectors themselves, are most familiar with the service areas and are thus best qualified to design the new system and routes. Second, their participation is apt to make them feel that the new system is their system, and thus they will be more likely to support it. And third, management, including supervisors and foremen, must be familiar with the new routings and other changes for supervisory, planning, and control purposes.

The solid waste collectors and drivers must be informed of all proposed changes in the collection system. They are the backbone of the system and need to be positively motivated and rewarded. They should be encouraged to comment on the effect of the changes on their daily operations. Their criticisms or suggestions for further improvement are essential to the final evaluation by the management staff; the collectors and drivers are frequently in the best position to explain route peculiarities and to help with route designs. In addition to being a potential source of pertinent input, the workers' participation in reviewing the decisions may be a positive influence in that it helps them feel a part of the new system.

To orient drivers to the new routings, each should be given a personal notebook containing a map of each daily route, which he may review and use during collection. The supervisor should retain a file copy of the route notebook.

Increased efficiency, almost by definition, means that fewer collectors will be required. It also means that more services will be collected per hour. These two factors, plus an understanding of the local labor relations situation, must be considered in determining when to notify collectors of a proposed change in their system, in presenting the change positively, and in deciding whether the collectors will assist in rerouting. Often, however, increased productivity can be achieved with a reduced labor force and, at the same time, a reduced workload for the remaining collectors. Also, increases in efficiency usually mean easier work for the employees—less walking and less lifting, as well as shorter hours.

If possible, reductions in manpower should be achieved not by firing employees, but by attrition, by transferring workers to street maintenance, parks, street cleaning, or other departments, or by starting a separate collection program for recyclable materials.

Several mechanisms can elicit cooperation from the collection personnel and ameliorate employee morale during and after implementation. Unless wages are already rather high, an increase may be considered in light of the increase in productivity (increased services per hour) and cost savings. Or the increased productivity may be rewarded by a new incentive system, e.g., the task system instead of a straight 8-hour day. Or, as done recently in Detroit, a plan may be started whereby the employees share in part of the savings accrued, in the form of cash bonuses.

Here is an example of how one community approached a reduction in crew size. The sanitation department decided to go from three- to two-man crews, and to predominantly curbside pickup. Implementation was carefully planned. First, the reduction was voluntary for each crew. Second, the whole labor force was not addressed at once, but implementation was done gradually, one district at a time. Each district saw a film showing backyard tote-barrel collection, collection from both sides of the street with three men, and collection from one side of the street with two men. Accompanying this film was a taped dialogue explaining how much easier the city had made it for the laborers in going from a backyard to a curbside system (there were no more tote barrels, fewer back injuries, less walking) and showing how three-man crews do so much more walking, waiting, and carrying of waste than do two-man crews.

Third, they discussed with the crews how much additional time the crews thought it would take for a two-man crew to collect the same routes the three-man crews were currently collecting; invariably, the crews felt it could be done in an 8-hour day. And fourth, for those crews who voluntarily elected the more efficient two-man crew size, the city would do three things: (1) share some of the resultant cost savings with the laborers, through increased wages, (2) promise not to fire anyone, (3) help these crews reduce their on-route times by designing new routes for the two-man crews. The new routes involved collecting one side of the street at a time and minimizing dead travel distance and left turns by applying the heuristic routing technique. When the crew members asked how the heuristic routing techniques would help them, the superintendent put up a three-block pattern as a simple example and asked one of the crew members how he would collect it. After the crew member attempted a solution, the superintendent showed the heuristic routing pattern, which eliminated dead distance. The heuristic solution was typically 20 to 50 percent as long as the route designed by the crew member.

Eighty-five percent of the crews elected the two-man crew initially. Most of the remaining reluctant crews soon wanted to join the "now" crew size for better pay, especially when the converted crews were finishing in almost the same amount of time. The next change was to one-man crews using right-hand side loaders. This was facilitated because the collector on a two-man crew must load almost twice as much as a loader on a one-man crew to be cost competitive. Also, one-man crews are typically paid more, carry greater responsibility, and command more respect.

City officials must be apprised of proposed changes, for several reasons: First, most of the organizational and service level policy changes (which significantly affect the citizenry) usually must be approved by the city officials or council. Second, the budget for the system, including capital outlays for new equipment, usually must be approved by the council. Third, city officials, persuaded of these changes, are often important allies during the transition. And fourth, city officials should be able to explain the changes to citizens who inquire about them.

Many city councils have voted against changes in solid waste collection for fear of citizen resistance, and many city officials have avoided making such proposals for fear of rejection by the councils. In 1974, one such council opposed a change to combined collection of food waste and other rubbish because they felt this would offend the citizens. Previously, the garbage had been collected separately and used by a hog farmer, but at the time the change was proposed, it was going to the landfill with the other wastes. Rather than let such a proposal die, its proponents could use a carefully prepared presentation of the advantages to get it adopted. Some of the advantages of combined collection are: (1) substantially lower cost, (2) fewer collection vehicles putting wear on the streets, presenting traffic hazards and delays, or making noise, (3) less fuel consumption, (4) easier handling at the landfill.

Councils also tend to resist going from backyard to curbside collection because they expect citizens to reject the aesthetic effect of temporarily storing waste at curbside. Yet communities that have been forced to change to curbside collection because of insufficient labor (resulting in missed collections) or insufficient funds (when citizens wanted the service but didn't want to pay for it) were surprised to find that the majority of citizens actually preferred curbside collection. Some of the arguments in favor of curbside collection are: (1) substantially lower cost (38 to 64 percent less than backyard collection), (2) fewer labor problems, such as turnover and absenteeism, (3) fewer injuries, particularly backstrains, but also dog bites and falls, (4) less fuel consumption, (5) fewer citizen complaints about such problems as gates left open, shrubs and flowers trampled, waste spilled, noise, missed collections, or collection of items not meant to be taken, and (6) less intrusion of privacy. Many communities, such as St. Petersburg, Florida, and Fort Worth, Texas, have been able to convert to curbside service by permitting those who really want backyard service and are willing to pay for it to opt for that level of service and the higher fee that goes with it. In both of these communities, only about 10 percent chose backyard service.

Another way to overcome the aesthetics problem and to make it easier for residents to carry waste to the curbside is to use large plastic cans (80 to 300 gallons) on wheels or in the alleys, or else paper or plastic sacks. Another consideration with curbside service is the aged and handicapped, who are typically allowed to apply for and receive backyard service, frequently at no additional charge.

One community designed a new collection system in 1974 for separate collection of newspapers. This design included new routes, a public relations information program, and the modification of a collection vehicle. But when presented to the decision-making authority (city council) for approval, it was voted down, primarily because of concern for public organizations (e.g., boy scouts) that periodically collect newspapers. If the council had been approached earlier, they might have approved the new system, or else much of the expense of planning could have been avoided.

There are about 75 communities which have converted to using paper or plastic sacks. In almost every one of these communities there seemed to be strong citizen resistance to such a conversion, but after the change was implemented followup surveys showed there was strong support for the sack systems. In fact, because of apparent citizen resistance, one community decided to quit using sacks, and found resistance to this even greater, so stayed with the sack system. In only a couple of cases was the sack system abandoned. Again, a tactful public education program is required. Plastic and paper sacks improve sanitation, hold in odors, do not cause problems in incinerators or sanitary landfills, improve collection efficiency, and decrease collection costs (since they are one-way collection items). Furthermore, after the crews collect the waste there are no cans to get windblown or stay on the curb until the homeowner recovers them, and they don't present any more of a problem because of animals than cans do.

THE PROCESS IN ACTION

The five-stage improvement process has been successfully applied by OSWMP in its major technical assistance projects. This section summarizes the results in some communities where the improvement process has been applied to improve service and/or decrease costs.

river rouge, michigan (18,000 population)

This was the first community in which OSWMP applied the five-stage improvement process. The improved collection system went into effect during the summer of 1971. Even though the original design of the new system (two two-man crews) was modified in a compromise with the labor union (to two three-man crews), the new system provided substantial savings in manpower and reduced injury expense. These savings resulted primarily from replacing the city-provided 55-gallon drums with plastic sacks and improving the scheduling and routings.

In the new system, collection is twice a week. Frequency of collection was erratic in the old system; it was supposed to be twice a week but was often more frequent and sometimes less.

With both systems, collections were made from alleys, an extra three-man crew was utilized for commercial collection, bulky items were collected by a private hauler contracted by the city, and there was a 30-minute round-trip haul and dump time.

savings achieved

Taking into account the cost of plastic sacks, the residential collection cost was cut from $202,562 to $85,551, a savings of 58 percent. The subsequent savings will be even greater as labor, equipment, and operating costs increase since there are now fewer men and fewer trucks in the system. In contrast, a neighboring community of similar size still used 55-gallon drums in 1973 and required nine three-man crews.

The separate bulk-waste pickup (by the private contractor) and the commercial collection systems were not evaluated.

huntington woods, michigan (8,536 population)

The city manager applied the five-stage improvement process and implemented three system changes in 1970 and 1971 as summarized below. He received technical assistance from the Southeast Oakland County Incinerator Authority, Michigan, and, for the second and third changes, from OSWMP.

Year	Change
1970	Two three-man crews* reduced to two two-man crews, primarily by changing from collecting two sides of the street to one side at a time, and by better scheduling (six men reduced to four).
1971	In August, one of the two-man crews was replaced by a one-man crew and vehicle (four men reduced to three).
1971	In October, route balancing, districting, and heuristic routing were implemented so that the one-man crew could collect the whole city in a week (three men reduced to one).

*Crew size includes driver as well as collectors.

When the final system was implemented, the city instituted a separate newspaper collection program. All other variables remained essentially the same. The Huntington Woods system is currently one of the most productive and least costly systems in the United States (Table 1).

TABLE 1

PRODUCTIVITY OF THE NEW SYSTEM, CITY OF HUNTINGTON WOODS, MICHIGAN

	June 1972 to May 1973	
	Averages	Ranges
Number of services per day (5 days/week)*	499	492-517
Number of tons per day*	12.8	
On-route collection minutes per home per day	.62	.47-.80
Length of workday (hours)	7.1	
Collection cost per ton†	$ 5.77	$4.75-$10.07
Collection cost per home per week†	$ .16	$ .13-$ .19

*Due to the separate collection of newspapers and the leaf collection by street sweeper, the average lb/home/week and daily tonnage collected by the one-man crew is 17 percent less than the 1971 average.

†These cost figures include equipment operating costs (gas, oil, tires), maintenance and repair (labor and parts), depreciation (5-year life, straight-line), and direct labor wages and fringe benefits, including 20 percent of the spare collector's cost. They do not include the cost of supervision, overhead, spare vehicle, or newspaper collection program.

The system provides 2,947 residences (almost all single-family, detached) with once-a-week, curbside collection service. An estimated 60 to 70 percent of the storage devices being used are plastic sacks (80 percent of the residences use at least some plastic sacks). The round-trip haul and disposal time per load is 45 minutes. The on-route distance per day averages 11.4 miles. The average waste amount during June 1972 to May 1973 was 51.3 pounds per home per week (not including the recycled newspaper).

savings achieved

When the actual 1972 cost is compared with what it would have cost in 1972 if the previous system had remained in effect, the total decrease in collection cost is $62,000 (Table 2). This represents a reduction of 65 percent over the pre-1970 system. The 1972 costs can be apportioned as follows:

Direct collection cost per home:
$.16/week, $.69/month, $8.32/year

TABLE 2

SAVINGS IN COLLECTION COSTS, CITY OF HUNTINGTON WOODS, MICHIGAN

	No. of collectors	No. of crews	1972 Collection costs		
			Labor*	Equipment†	Totals‡
1972 system	1	1	$23,700	$ 9,000	$32,700
Pre-1970 system	6	2	79,700	15,000	94,700

*Includes extra labor (substitute crew) and allocated share of supervisory and administrative personnel; direct labor is $4.77/hour (wages and fringe benefits).
†Includes operating, repair and maintenance, and depreciation expense (5-year life, straight-line); does not include depreciation cost of spare vehicle, which is currently used for newspaper collection.
‡Includes labor overhead but excludes building overhead; does not include disposal costs.

Total collection cost per home:
$.25/week, $1.09/month, $13.10/year

Direct cost includes all equipment and collection labor cost, including spare labor cost. Total cost includes all overhead except building. In addition, since the city collects newspapers separately, it receives $20 to $25 per ton for the newspapers and saves a disposal charge of $7.25 per ton.

portland, maine (64,000 population)

In 1972, OSWMP assisted the city's public works director in applying the five-stage improvement process. Using collection routing design techniques, the new system achieved projected cost savings while substantially increasing the level of service it provided its residents.

Previously, garbage was collected once a week by a private contractor, and nongarbage wastes were collected every other week by five three-man city crews. Municipal collection was not available to about a third of the apartment units. Under the new system, city crews collect the combined wastes once a week, and municipal service is available to all residential units. The number of city crews (three-man) was increased from five to seven.

savings achieved

A projected annual savings of $30,000, including the savings from the garbage collection contract, will be achieved, despite the higher level of service.

akron, ohio (272,000 population)

OSWMP assisted Akron's department of public service in applying the five-stage improvement process to design a new system. It was implemented on August 6, 1973, with very few problems and has afforded substantial savings to the citizens. The major changes in the system were:

Under the previous system, there was backyard collection of garbage only, once every 7 working days by the city crews. The remaining refuse was collected by a private hauler contracted by individual homeowners. Under the new system, there is curbside collection of combined wastes once a week. Four-fifths of the city is collected by the same city forces that existed before the change. One-fifth of the city is collected by a private hauler contracted by the city.

The old city policy of separate collection caused duplication of effort by city and private forces. The new system increased the frequency of garbage collection.

savings achieved

Preliminary estimates show a total savings to citizens of Akron of $2.2 million per year, or $30 per residence per year.

the southeast oakland county incinerator authority michigan (SOCIA), (360,000 population, 14 communities)

The authority, with the assistance of OSWMP, applied the five-stage improvement process to help the member communities achieve a reduction of approximately 22 percent in direct collection costs authority-wide, with a projected 11-percent additional savings potential when all communities implement improved systems. These savings were achieved without a change in level of service (once-a-week, curbside, authority-wide). They resulted from better routings, more efficient crew sizes and equipment, better scheduling, more efficient collection methods, and the competitiveness developed among crews and systems. With increasing labor rates, the savings are becoming even greater. SOCIA is discussed further in the Appendix.

Other communities OSWMP has assisted in improving their systems using the five-stage improvement process include Albany, New York; St. Petersburg, Florida; Reston, Virginia; Falls Church, Virginia; and Coventry, Rhode Island. Communities which have used a similar method to evaluate their collection systems and achieved substantial savings include Inglewood, Santa Clara, Covina, and San Fernando, California; Salt Lake County, Utah; Fort Worth, Texas; and Kansas City, Missouri.

inglewood, california (95,000 population)

Through carefully planned implementation programs, good public relations work, and sound personnel management, as well as application of one of the best technological systems (one-man vehicle and plastic sacks), Inglewood has developed one of the most efficient and responsive collection systems in the United States today. The city reduced its costs substantially between 1960 and 1970, while handling a waste load that increased by 54.7 percent during the same period (Table 3). Even with 60 percent inflation between 1960 and 1970, the city still reduced its labor costs per ton by 30.1 percent.

fort worth, texas (393,000 population)

Recognizing the high cost of backyard collection service and the difficulty of alley collection (there were many unpaved alleys) this

TABLE 3

COLLECTION SYSTEMS IN 1960 AND 1971, INGLEWOOD, CALIFORNIA

	Jan. 1, 1960	Jan. 1, 1971	Percent increase or decrease
Population	66,598	95,000	+42.6
Dwelling units	25,330	33,031	+50.1
Annual tons of refuse	24,265	37,531	+54.7
Number of trucks in fleet	29	16	-44.8
Total truck loads	5,855	4,335	-26.0
Annual man-hours	52,167	36,534	-30.0
Man-hours per ton	2.19	.97	-55.7

city converted to a predominantly plastic sack, curbside collection system and established, in January 1970, a user charge to reflect the actual cost of collection. These charges were $3.50 per month for backyard service and $2.00 per month for curbside service, which increased in January 1972 to $5.00 per month and $2.50 per month respectively.

savings achieved

Productivity increased from 2.0 to 4.1 tons per man per day from 1969/70 to 1970/71, and cost decreased from $17.25 per ton to an estimated $14.73 per ton. This represents a 14.6 percent cost reduction despite incentive pay of $.10 for each crew member for each backyard pickup.

APPENDIX

collection management information system (colmis) for residential solid waste collection

objective of COLMIS

The basis of effective management and decision-making is the availability of reliable information on the system being managed. Lack of information can lead to loss of control, and good information can serve as the basis for improvements and cost savings.

Solid waste management requires definitive information on the operational aspects of collection and the costs involved in providing this service.

A good way to obtain the required information is through the use of a computerized reporting system. One such system is COLMIS, Collection Management Information System, available from EPA at no charge. Through COLMIS it is possible to collect, store, and process large quantities of productivity and cost data and to generate reports with different levels of detail for the various levels of management.

While serving as a creditable record of operational and cost information, these reports are a valuable planning tool. Information from these reports can be used to evaluate the present system and to design new systems. They provide the specific data needed for macro-routing (stage 2), determining a fair day's work for each crew for route balancing (stage 3), estimating truck and crew requirements for the entire system, and projecting trends in the system (particularly costs and amounts of waste). They can also aid in determining the useful life for equipment and thus help in planning a capital replacement program.

COLMIS and its utilization are explained further in the publication *A User's Manual for COLMIS, A Collection Management Information System for Solid Waste Management.*[3,4] Volume I of this report is a description of COLMIS utilization and Volume II lists the computer program and gives additional installation details.

some questions the COLMIS reports help answer

1. What are the actual collection costs per home and per ton?
2. How much waste is collected per home per week? How does this vary seasonally?
3. Which are the most productive and least productive crews?
4. Which crew size is most economical?
5. Are the collection routes reasonably balanced?
6. What are the high-cost items?
7. How many residences are serviced per crew per collection hour?
8. How effectively are the equipment capacities being utilized? What are their density capabilities?
9. What are equipment operating costs? When should equipment be replaced?
10. How many services constitute a load for different generation rates?
11. How are productivity and costs affected by different collection frequencies, equipment types, storage devices, and other methodologies?

cost effectiveness of COLMIS

Effective use of this type of analysis can lead to significant results. Fourteen of the 35 communities in which the COLMIS program has been installed are in the same regional authority in Michigan, the Southeast Oakland County Incinerator Authority, which serves a population of 360,000. Management information from COLMIS and assistance from the authority and EPA in routing and evaluating crew sizes, equipment types, and collection methodologies enabled these communities to maintain the same level of service (once-a-week, curbside) while cutting direct annual collection costs by 16.7 percent within a 6-month period, and 18.5 percent in the first year. In the first year and a half, approximately 22 percent was saved, with a potential of another 11 percent if all the communities and routes are converted to the most efficient systems that have been identified. Part of this savings was due to the competitive situation created among the crews and managers because the performance of each crew and system was documented by COLMIS. Five of the systems are run by private contractors, who are becoming a part of this competitive situation between communities to improve their efficiency, as evidenced by the fact that all new contracts are either below or at the same cost as the previous 3-year contracts.

The cost effectiveness of COLMIS can be seen by comparing its cost to the savings achieved. The total computer cost for processing the data, including keypunching, is $5,200 per year, or an investment of 1.4 cents per person per year; the resultant savings amounted to 81 cents per person for the first year—certainly a worthwhile investment.

input information required

COLMIS requires two types of input information: background and daily. The background information is stored in the computer and can be changed when necessary. It includes:

District information: number of routes, normal workday (hours), overtime factor, lunch time, and collection frequency.

Route information: route number, wages of drivers and collectors, average number of persons per home, number of collection days per week, and collection days.

Vehicle information: vehicle number, vehicle type (e.g., rear, side, or front loader), vehicle size (cubic yards), fuel cost per gallon, oil cost per quart, maintenance cost per day, depreciation cost per day, and tare weight.

The daily information is recorded each operating day by the packer-truck driver on a simple Daily Collection Route report form (Figure 13). This daily information is keypunched directly off this form for computer input.

output information

There are six types of COLMIS output reports:

The *Editing Report* shows the completeness of data supplied and provides a gross check on the correctness of data input.

The *Route Information Report* shows how the crew spends its time on the route and the work performed: motor pool to route (time and miles per day), collection operation (time and miles per day), transport operation (time and miles per day), total time to route, collect

ANY CITY, U.S.A.

DAILY COLLECTION ROUTE INFORMATION

ROUTE ____________ DATE ____________ DAY ____________ CREW SIZE ____________

VEHICLE NO. ____________ FUEL (GAL) ________ ENG. OIL (QT) ____________

NO. HOMES SERVED ____________	TIME	MILES	WEIGHT	DISCHARGE POINT *
LEAVE MOTOR POOL				
START COLLECTION				
LEAVE ROUTE				
AT DISCHARGE POINT				
ARRIVE BACK ON ROUTE				
LEAVE ROUTE				
AT DISCHARGE POINT				
ARRIVE BACK ON ROUTE				
LEAVE ROUTE				
AT DISCHARGE POINT				
ARRIVE BACK ON ROUTE				
LEAVE ROUTE				
AT DISCHARGE POINT				
ARRIVE BACK ON ROUTE				
LEAVE ROUTE				
AT DISCHARGE POINT				
ARRIVE AT MOTOR POOL				

			BREAKDOWN – PROBLEM (Circle Number)
LUNCH – START			1 Brakes, wheels, tires
– FINISH			2 Cooling or exhaust sys
BREAKDOWN – START			3 Electrical sys 4 Fuel sys
– FINISH			5 Packer 6 Power or steering sys
VEHICLE REPLACED			7 Other

* ENTER NUMBER
1 = INCINERATOR
2 = LANDFILL
3 TRANSFER STATION

REMARKS:

DATA VERIFIED BY: ____________

Figure 13. The drivers record information on this Daily Collection Route report form. Information is then keypunched directly off this form for computer input.

and transport (hours), downtime (hours), lunch time (hours), weight per day (pounds and tons).

The *Collection Information Report* gives crew productivity ratios on weight and time basis: homes served per collection day; weight per collection day (pounds); persons served per collection day, generation rate per person per day (pounds); collection time per home (minutes); collection time per 100 pounds (minutes); collection time as percent of total time worked; total time worked as percent of standard time; loads per day to incinerator, landfill, or transfer station; weight per cubic yard of first load (pounds).

The *Collection Cost Information Report* gives average daily cost figures for the collection and transport functions in dollars: cost from motor pool to route, cost of collection operation, cost of transport operation, equipment costs per day, manpower cost per day, total costs per day, costs of manpower during equipment down periods, incentive costs, overtime costs, cost per ton, and weekly and yearly costs per home.

The *Collection System Operation Summary* summarizes key information already given in the route, collection, and cost reports.

The *Management Analysis Report* comparatively rates the performance of crews or organizational units on ten performance indicators, such as weight collected and homes served.

For each of these reports, different levels of reports for different managerial levels may be produced based on the amount of data clustered into the figures in the reports. The clustering is of two types; data is combined for different time periods (weekly or monthly) and for different sets of crews. These reports are:

1. *Weekly Report:* one set showing the day-by-day performance of each crew is used by the immediate supervisors of the crews. Reports for middle management give only a summary of weekly activities for each crew. Higher management level reports combine crews into districts, etc. The management analysis report is useful to all levels of management.

2. *Monthly Report:* summarizes on a monthly basis the information supplied by the weekly reports.

All of the reports, except the editing report, give year-to-date figures for ready comparisons with the current period.

ABSTRACT

Shuster, Kenneth A. *A Five-Stage Improvement Process for Solid Waste Collection Systems,* U.S. Environmental Protection Agency, 1974.

This report describes a five-stage improvement process for solid waste collection systems that can increase productivity and reduce costs of solid waste collection. The process was developed by EPA and has been used quite extensively and successfully to critically evaluate and redesign local collection systems. It is based in large part on information developed by EPA on productivity and cost which can be used to predict the effects of various courses of action. More detailed reports on specific stages and tools are available from EPA.

REFERENCES

1. Office of Solid Waste Management Programs. Decision-makers guide in solid waste management. Environmental Protection Publication SW-127 Washington, U.S. Government Printing Office, 1974. 157 p.
2. Shuster, K. A., and D. A. Schur. Heuristic routing for solid waste collection vehicles. Environmental Protection Publication SW-113. Washington, U.S. Government Printing Office, 1974. 45 p.
3. User's manual for COLMIS: a collection management information system for solid waste management. v. 1. Environmental Protection Publication SW-57c. Washington, U.S. Environmental Protection Agency, 1974. 99 p.
4. User's manual for COLMIS: a collection management information system for solid waste management. v. 2. Environmental Protection Publication SW-58c. Washington, U.S. Environmental Protection Agency, 1974. 49 p., app.

All of the above reports are available from EPA upon request to the Solid Waste Information Control Section, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268.

μσ1038

☆ U S GOVERNMENT PRINTING OFFICE 1975— 582-417/197